



Chapter 7: Marlinespike Seamanship



Overview

Introduction

Marlinespike Seamanship is the art of handling and working with all kinds of line or rope. It includes knotting, splicing, and fancy decorative work. There is no better measure of a sailor's worth than skill in marlinespike seamanship. Much practice is required to become proficient in this skill. Knowledge of line handling terminology, phrases and standard communication among the crew is necessary. To be less than proficient may be costly when the safety of LIFE and PROPERTY depends on the crew's knowledge of marlinespike seamanship.

This chapter contains information about the types, characteristics, use, and care of line. You will find definitions, safety practices, and line handling commands, as well as directions for tying knots and making splices commonly used on Coast Guard boats and Auxiliary facilities. Included are instructions about basic boat line handling. Finally, you will find technical information for determining which line, hooks, and shackles are safe to use.

In this chapter

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Coast Guard Boat Crew Seamanship Manual





Section A. Types and Characteristics of Line

Overview

Introduction

The uses for a particular line will depend heavily upon the type and characteristics of the line. This section includes information regarding the different types of line used in boat handling.

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These items are discussed in this section:

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Line Characteristics

A.1. General line construction

Lines are made of natural or synthetic fibers twisted into yarns. The yarns are grouped together in such a way to form strands. Finally, the strands are twisted, plaited, or braided, in various patterns, to form line.

A.2. Coast Guard line

Line used on Coast Guard boats is classified in two different ways: material used, and construction of the line.

A.2.a. Material used

Lines are categorized as natural fiber or synthetic fiber. Refer to Figure 7-1 for fiber line characteristics. The characteristics of the natural and synthetic fiber lines will be explained further in this section.



LINE	NA	TURAL FIBER L	INE		SYNTHETIC FIBER LINE			
CHARACTERISTICS	Manila	Sisal	Cotton	Cotton Nylon		Polypro- pylene	Poly-ethylene	
Strength: Wall strength compared to dry strength	Up to 120%	Up to 120%	Up to 120%	85-90% ¹	100%1	100%	105%	
Shock load absorption ability	Poor	Poor	Poor	Excellent	Very Good	Very Good	Fair	
Weight: Specific gravity Able to float	1.38 No	1.38 No	1.54 No	1.14 No	1.38 No	.91 Yes	.95 Yes	
Elongation: Percent at break	10-12%	10-12%	5-12%	15-28%	12-15%	18-22%	20-24%	
Creep (extension under sustained load)	Very Low	Very Low		Moderate	Low	High	High	
Effects of Moisture: Water absorption of individual fibers	Up to 100%	Up to 100%	Up to 100%	2.0-6.0%	<1.0%	None	None	
Resistance to rot, mildew, and deterioration due to marine organisms	Poor	Very Poor	Very Poor	Excellent	Excellent	Excellent	Excellent	
Degradation: Resistance to U.V. in sunlight Resistance to aging for	Good	Good	Good	Good	Excellent	Fair ²	Fair ²	
property store rope	Good	Good	Good	Excellent	Excellent	Excellent	Excellent	
Rope Abrasion Resistance Surface Internal	Good Good	Fair Good	Poor Good	Very Good ³ Very Good ³	Very Good ¹ Excellent ¹	Good Good	Fair Good	
Thermal Properties: High temperature working limit	300 ° F	300 ° F	300 ° F	250 ° F	275 ° F	200 ° F	150 ° F	
Low temperature working limit Melts at	-100 ° F	-100 ° F	-100 ° F Chars 300 ° F	-70 ° F 490-500 ° F	-70 ° F 490-500 ° F	-20 ° F 330 ° F	-100 ° F 285 ° F	
Chemical Resistance: Effects of Acid	Will disintegrate in hot diluted and cold concentrated acids	Same as Manila	Same as Manila	Decompose by strong mineral acids; resistant to weak acids	Resistant to most mineral acids; disintegrate by 95% sulfuric acid	Very Resistant	Very Resistant	
Effect of alkalis	Poor Resistance will lose strength where exposed	Same as Manila	May swell but will not be damaged	Little or none	No effect cold; slowly disintegrate by strong alkalis at the boil	Very Resistant	Very Resistant	
Effect of organic solvents	Fair resistance for fiber ,but hydrocar-bons will remove protective lubricants on rope	Good Resistance	Poor Resistance	Resistant. Soluble in some phenolic compounds and in 90% formic acid	Generally unaffected; soluble in some phenolic compounds	Soluble in chlorinated hydrocar-bons at 160 ° F	Same as polypro-pylene	

Grades with special overfinishes are available to enhance wet strength and abrasion properties.

For non-UV stabilized product, consult manufacturer.

Dry condition. Under wet condition: Good.

Fiber Line Characteristics Figure 7-1

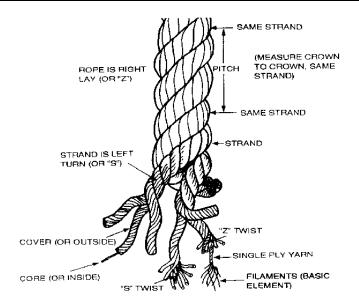


A.2.b. Construction

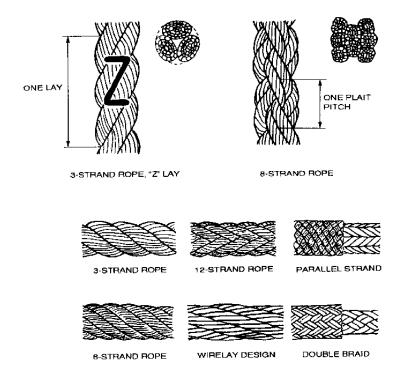
Strands are twisted to either the right or the left. This twisting is the "lay" of the line. Line may have either a left lay or a right lay depending upon how the strands are twisted together. Line is usually constructed as plain laid, plaited, and double braided lines. Figure 7-2 illustrates fiber rope components and construction. The type of construction will depend upon the intended use of the line.

Type	Characteristics
Plain laid	Made of three strands, right or left-laid. Most
	common is right-hand laid.
Cable laid	Made of three, right-hand, plain-laid lines laid
	together to the left to make a larger cable.
Plaited line	Made of eight strands, four right-twisted and four
	left-twisted. Strands are paired and worked like a
	four strand braid.
Braided line	Usually made from three strands (sometimes four)
	braided together. The more common braided lines
	are hollow-braided, stuffer-braided, solid-braided,
	and double braided.
Double braided line	Two hollow-braided ropes, one inside the other.
	The core is made of large single yarns in a slack
	braid. The cover is also made of large single yarns
	but in a tight braid that compresses and holds the
	core. This line is manufactured only from
	synthetics, and about 50% of the strength is in the
	core.





THREE-STRAND ROPE COMPONENTS



Fiber Rope Components and Construction Figure 7-2



Natural Fiber Line

A.3. Composition

Natural fiber line is made from organic material, specifically, plant fiber. The table below describes the various natural fiber lines.

Type	Description
Manila	Made from fibers of the abaca plant and is the strongest and
	most expensive of the natural fibers.
Sisal	Made from the agave plant and is next in strength to manila,
	being rated at 80% of manila's strength.
Hemp	Made from the fiber of the stalk of the hemp plant, is now
	rarely used.
Cotton	Made from natural fibers of the cotton plant, may be three-
	stranded, right-lay or of braided construction used for fancy
	work and lashings.

A.4. Uses of natural fiber line

We use natural fiber lines, usually manila, hemp or sisal, for tying off fenders, securing chafing gear, and other small stuff (i.e., line 1¾ in. in circumference and smaller) uses.

Braided line is most commonly used for signal halyard, heaving lines, and lead lines.

Plain laid line maybe used for towlines, mooring lines, anchoring, securing loose gear, fender lines, and fancy work.

A.5. Limitations

CAUTION!

Do not use natural fiber line as a towline.

Natural fiber line has a lower breaking strength than synthetic fiber line of an equal size, and unlike synthetic line, natural fiber line does not recover after being stretched (elasticity). In the Coast Guard, we do not use it for load bearing purposes on boats. Another limitation of natural fiber line is the liklihood of rotting if stowed wet.

A.6. Construction

A close look at a natural fiber line will reveal that the strands are twisted together. They will have either a right or left lay.



A.7. Plain laid lines

Plain laid line is the most common type of natural fiber line used in the Coast Guard. In plain laid three strands are twisted together to the right in an alternating pattern. Because of the number of strands, this line is sometimes called "three strand" line. The yarns making up the strands are laid in the opposite direction of the strands. These are twisted together in the opposite direction to make the line. The direction of the twist determines the lay of the line. In the case of plain laid lines, the yarns are twisted to the right. They are then twisted together to the left to make the strands. The strands are twisted together to the right to make the line (See figure 7-2).



Synthetic Line

A.8. Composition

Synthetic line is made of inorganic (man-made) materials. The characteristics of synthetic line are considerably different from natural fiber line. The differences will vary depending on the type of from which the line is made. The table below identifies the various types of synthetic fiber line used.

Type	Description
Nylon	A synthetic fiber of great strength, elasticity, and
	resistance to weather. It comes in twisted, braided, and
	plaited construction, and can be used for almost any
	purpose where its slippery surface and elasticity is not a
	disadvantage.
Dacron	A synthetic fiber of about 80% if the strength of nylon
	but will only stretch 10% of its original length.
Polyethelene	A synthetic fiber of about half the strength of nylon, 25%
and	lighter than nylon making it easier to handle, and floats in
Polypropylene	water.

A.9. Commonly used types

The most common types of synthetic line used on Coast Guard boats are nylon and polypropylene. Because of its superior strength and elasticity, nylon is used where the line must bear a load.

A.10. Double braided nylon line

Double braided nylon line is the only line used for towlines on Coast Guard boats. However, Auxiliary facilities use towlines of various types and sizes. When double braided line is made, the yarns are woven together much like the individual yarns in a piece of cloth are woven. The actual line consists of two hollow braid lines, an inner core and an outer cover. The core is woven into a slack, limp braid from large single yarns. The cover is woven from even larger yarns into a tight braid to cover and compress the core.

A.10.a. Elongation and elasticity

Double braided nylon has two other characteristics which increase its strength. These are elongation and elasticity. Elongation refers to the stretch of the line and elasticity refers to the ability of the line to recover from elongation. Synthetic line will stretch farther and recover better than natural line. Because of this, synthetic line can absorb the intermittent forces and surges resulting from waves or seas much better than natural fiber line.



A.10.b. Limitations

While its superior strength makes double braided nylon line the preferred choice for load bearing there are disadvantages. Because it will stretch further (elongate) and still recover (elasticity), the snap back potential if the line parts is greater than with natural fiber line. Also, if nylon line is doubled and placed under excessive strain, there is a danger that the deck fittings might fail. If that happens, the line will snap back like a rubber band, bringing the deck fitting with it. Additionally, damage to the engine or deck fittings could occur if the bollard pull is exceeded.

A.10.c. Definition

Bollard pull is the point where the static pulling force becomes such that any increase in engine load could lead to damage to the engine or the towing bitt.

CAUTION!

Never double a line or use a single line which can withstand more pulling force than the bollard pull of the towing bitt.

A.11. Plain laid polypropylene line

Orange colored polypropylene line is used on Coast Guard boats for life rings, and kapok heaving lines. The advantage to this line is high visibility and floatation.

A.11.a. Limitations

The main disadvantage is lack of strength compared to nylon line of equal size. Its loose course weave makes it easy to splice but susceptible to chafing. Aggravating this is polypropylene's characteristic of deteriorating rapidly when exposed to continuous sunlight. It can in fact, lose up to 40% of its strength over three months of exposure. For this reason the line is best kept covered when not in use, and inspected and replaced on a regular basis.

A.12. Slippage

Synthetic line slips much easier than natural line. Because of this, it will slip through deck fittings and not hold knots as well. Be careful when bending synthetic line to an object or to another line to ensure the knot will not slip out. One way to help prevent this is to leave a longer tail on the running or bitter end than you would with natural fiber line.

A.13. Considerations

When using synthetic lines consider the following:

- Synthetic line will slip more easily than natural fiber line. You must use caution when paying it or surging it from deck fittings.
- Beware of slippage when bending synthetic line together or securing it.



- Never stand in any position exposing yourself to the dangers of snap back if the line parts.
- Do not double up the line during a towing operation.
- Keep working surfaces of bitts free of paint and rust.
- Do not stand in the bight of a line or directly in line with its direction of pull.

CAUTION!

To minimize the hazard of being pulled into a deck fitting when a line suddenly surges ensure all crew members stand as far as possible from the equipment. Work the lines with your hands a safe distance from the fittings. This is particularly important during towing operations.

A.14. Cutting

NOTE &

Remember, when a piece of rope is cut, it will fray. Always finish the end of the line whether before or immediately after cutting the line.

The use of a hot knife is the preferred method for cutting nylon and polypropylene line. Using a hot knife eliminates the need for burning the ends. Commercial electric knives, used by sail makers, are available. Some soldering irons can be fit with blades for cutting line. The most accessible method for most people is to heat an old knife or scraper using a propane torch.

When cutting the line, let the heat do the job. Do not force the blade or saw through the line The best method is to work from the outside in. First, an incision is made around the circumference of the line. Then cut through the center.



Section B. Inspection, Handling, Maintenance, and Stowage of Line

Overview

Introduction

Boat crewmen must know how to inspect, handle, maintain, and stow line. This section provides the necessary information regarding basic inspection, maintenance, and stowage of line.

In this section

These items are discussed in this section:

Topic	See Page
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Uncoiling and Unreeling	7-17
Maintenance	7-20
Stowing Lines	7-23



Inspection

B.1. General

A periodic inspection of all lines used should be made, paying special attention to the following items:

- Aging
- Fiber wear
- Fiber damage
- Chafing
- Kinks
- Cockles
- Cutting
- Overloading or shockloading
- Rust
- Eye splices

B.1.a. Aging

CAUTION!

Synthetic double braided line should not be taken apart for internal inspection. Aging affects natural fibers more severely than synthetic. Cellulose, the main component in natural fibers will deteriorate with age, getting more brittle and turning yellow or brownish. When bent over bitts or cleats, the fibers easily rupture and break. During bending, line strength may decrease up to five times. To check for aging, open the lay of the line and note the color of the interior fibers. In an old line they will be gray or dark brown. Aging is not a significant problem for nylon line, though it will change its color with age. As stated before though, polypropylene line does deteriorate rapidly when exposed to sunlight.

B.1.b. Fiber wear

When natural fiber line is under strain, the friction of the fibers, yarns and strands against each other, causes internal wear. You can check for internal wear when you check for aging. Upon opening the lay of the line, look for the presence of a white powdery substance. This residue is small particles of line worn off by friction.



B.1.c. Fiber damage

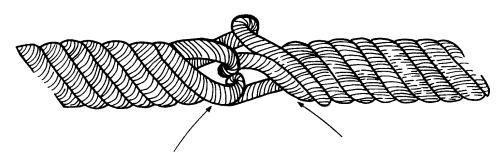
Damage to internal natural fibers occurs when a line under a strain exceeds 75% of its breaking strength. Although this load is not enough to part the line, it is enough to cause some of the internal fibers to break. Check for internal fiber damage when you check for aging and internal wear. Internal broken fibers indicates that the line has been damaged. With synthetic line some of the individual synthetic fibers of the line may break if overloaded. These will be visible on the outer surface of the line.

B.1.d. Chafing

Chafing is wear affecting the outer surface of a line, caused by the friction of the line rubbing against a rough surface. To check for chafing, visually inspect the outer surface of the line for frayed threads and broken or flattened strands. With synthetic line, chafing can also cause hardening and fusing of the outer layer.

B.1.e. Kinks

A kink (Figure 7-3) is a twist or curl caused when the line doubles back on itself. Never place a line with a kink in it under strain. The tension will put a permanent distortion in the line. Remove all kinks before using a line.



Line with a Kink Figure 7-3

B.1.f. Cockles

A cockle (or hockle) is actually a kink in an inner yarn that forces the yarns to the surface. Cockles can be corrected by stretching the line and twisting the free end to restore the original lay. A cockle can reduce line strength by as much as a third.

NOTE &

Braided line will not kink or hockle.

B.1.g. Cutting

A line damaged by cutting will usually show brooming and yarn end protrusion. This can weaken the line and probably cause line failure under strain.



B.1.h. Overloading or shock-loading

Signs that a line was overloaded are stretch out and hardness. Line stretched to the point where it will not come back has a decreased diameter. To determine this place the line under slight tension and measure the circumference of a reduced area and of a normal area. If the circumference is reduced by five percent or more, replace the line.

Another indication of synthetic line overloading, is hardness to the touch. You will notice this hardness if you gently squeeze the line. Don't use overloaded line.

A line under strain is dangerous. If it parts, it will do so with a lot of force, depending on the size and type of line, and how much strain it is under when it parts. As a general rule, when a line is under stress, always keep an eye on it. If you stand in line with the strain you might be seriously injured if the line parts an snaps back at you.

B.1.i. Rust

Rust stains, extending into the cross section of natural fiber and nylon fiber yarns can lower line strength as much as 40%.

B.1.j. Eye splices (double braided nylon line)

Prior to each use inspect all eye splices in your towline and side lines (mooring lines). Pay particular attention to the female section ensuring there are not "flat spots" where the crossover is buried at the base of the eye. Also inspect the entire eye for chafing and cuts. (See Appendix 7-D for illustrations.)



Uncoiling and Unreeling

B.2. General

Proper use and care will significantly extend the lifetime of the lines used. Everyone should be responsible for protecting lines from damage. Along with good inspections some of the ways to accomplish this are proper breakout, stowage, and care.

NOTE &

Never permanently cover natural fiber line with anything that will prevent the evaporation of moisture.

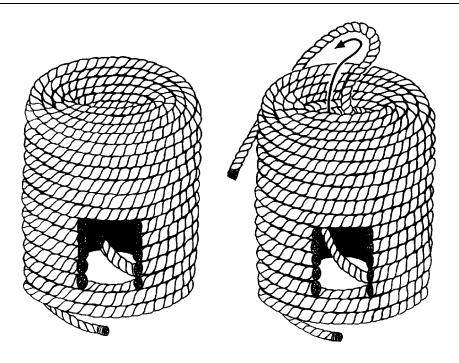
B.3. Uncoiling natural fiber laid line

To uncoil natural fiber laid line, follow these steps:

Step	Procedure
1	Look inside the center tunnel of the coil to locate the end of the
	line.
2	Position the coil so the inside line end is at the bottom of the
	center tunnel.
3	Start uncoiling the line by drawing the INSIDE END UP
	THROUGH THE TOP OF THE TUNNEL. (See figure 7-4)

Do not pull on any kinks that develop, as they will develop into permanent strand cockles. If kinks develop, lay the line out straight and remove them before use.





Opening a New Coil of Line Figure 7-4

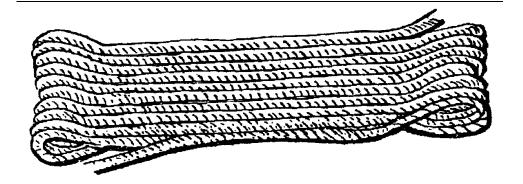
B.4. Unreeling synthetic fiber line

The recommended method for unreeling synthetic fiber lines is to:

- Insert a pipe through the center and hang the reel off the deck.
- Draw the line from the lower reel surface.

DO NOT "throw" twisted fiber lines off the reel as it will cause tangles and kinks. It is recommended that three strand synthetic lines be faked down on deck and allowed to relax for twenty four hours. Lengths less than 50 feet will relax in one hour when laid out straight. Fake down double braided line in figure eight patterns. (See figure 7-5)





Line Faked Down Figure 7-5



Maintenance

B.5. Basic line maintenance

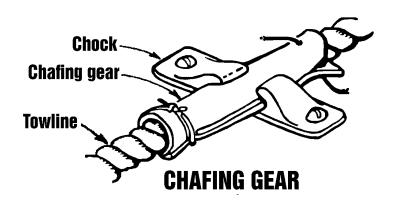
While there is not anything that can be done to restore bad line, there are precautions to take to lengthen its lifetime. The following are some of the things that can be done to extend the life of lines.

B.5.a. Keep lines clean

Keep lines free from grit or dirt. Gritty material can work down into the fibers while a line is relaxed. Under tension the movement of the grit will act as an abrasive and will cause serious damage to the fibers.

B.5.b. Use chafing gear

Chafing gear is made of old hoses, leather, or heavy canvas. It is used to protect short pieces of line where they run over taff rails, chocks, or other surfaces (See Figure 7-6).



Chafing Gear Figure 7-6

B.5.c. Keep deck fittings clean and smooth

Bitts, cleats, and chock surfaces should be kept smooth to reduce line abrasion.

B.5.d. Watch for frozen water

Do not let water freeze on lines. Ice is abrasive and can cut fibers.

B.5.e. Crushing or pinching lines

Do not walk on, place loads on, drag loads over, or in other ways crush or pinch a line.



B.5.f. Sharp bends

Bending under a load causes internal abrasion between the strands of the line. If a line has to go around something, use a fair lead. A fair lead is any hole, bull's-eye, lizard, suitably placed roller, sheave, etc., serving to guide or *lead* a rope in a desired direction. If a fair lead is not used, remember that the bigger the bend, the less the abrasive effect.

B.6. Care of natural fiber line

The practices that should be avoided or observed in the maintenance of natural fiber line are as follows:

	Dos		Don'ts
•	Dry line before stowing it.	•	Stow wet or damp line in an
•	Protect line from weather		unventilated compartment or
	when possible.		cover it so that it cannot dry.
•	Use chafing gear (canvas,		Mildew will form and weaken the
	short lengths of old fire hose,		fibers.
	etc.) where line runs over	•	Subject the line to intense heat or
	sharp edges or rough surfaces.		unnecessarily allow it to lie in the
•	Slack off taut lines when it		hot sun. The lubricant will dry
	rains. Wet lines shrink and if		out, thus shortening the useful
	the line is taut, the resulting		life of the line.
	strain may be enough to break	•	Subject a line to loads exceeding
	some of the fibers.		its safe working load. Individual
•	Reverse turns on winches		fibers will break, reducing the
	periodically to keep out the		strength.
	kinks.	•	Allow line to bear on sharp edges
•	Lay right-laid lines clockwise		or run over rough surfaces.
	on reels or capstans and left-	•	Scrub line. The lubricant will be
	lain lines counterclockwise		washed away, and caustics in
	until they are broken in.		strong soap may harm the fibers.
•	Inspect lines for fiber damage	•	Try to lubricate line. The
	and other wear conditions		lubricant you add may do more
	before each use.		harm than good.
•	Try to tie knots or hitches in	•	Put a strain on a line with a kink
	new places as much as		in it.
	possible so as not to wear out	•	Let wear become localized in one
	the line.		spot.
•	Occasionally end-for-ending	•	Unbalance line by continued use
	(swap one end for the other)		on winch in same direction.
	to help reduce excessive wear		
	at certain points.		



B.7. Care of synthetic fiber line

Most of the practices in the maintenance of natural fiber line are the same for synthetic fiber line. However, the differences are as follows:

- Nylon is not subject to mildew, and it may and should be scrubbed if it becomes slippery because of oil or grease. Spots may be removed by cleaning with light oils such as kerosene or diesel oil, or with liquid soap and water.
- Synthetic line stretches when put under a load. Allow plenty of time for the line to recover to its original length before coiling on a drum or reel.



Stowing Lines

B.8. General

To prevent the deteriorating effects of sunlight, chemicals, paints soaps, and linseed or cotton seed oils, store lines to prevent contact with harmful items or conditions.

B.9. Natural fiber lines

Natural fiber lines can be damaged by contact with just about anything. They are especially susceptible to the rotting and mildewing effects of moisture. After use, allow natural fiber line to dry thoroughly and stow it in a cool, dark, well ventilated space.

Synthetic fiber lines are not as susceptible to the effects of moisture as

B.10. Synthetic fiber lines

natural fiber lines. They are though affected by all of the other conditions and materials that will hurt line. Keep the boat's towline and other synthetic lines covered or stored in a dark area, when not in use.

NOTE &

Synthetic line should not be constantly coiled in the same direction as doing this tends to tighten the twist. Three-strand synthetic line is often coiled clockwise to reduce a natural tendency to tighten up. It can be coiled in figure eights to avoid kinks when paying out. (See figure 7-7)

Stow lines in designated space when not in use.

Whereas synthetic line stretches when put under a load, allow plenty of time for the line to recover to its original length before coiling on a drum or reel.



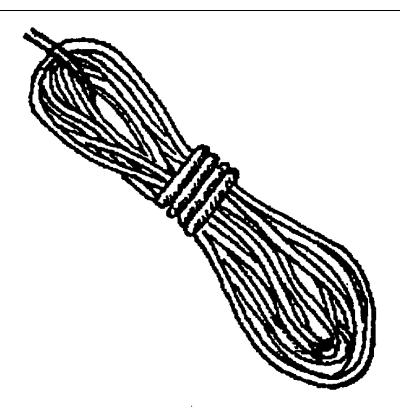


Figure Eight Coils
Figure 7-7

B.11. Towline

See Chapter 17 - Towing for procedures to stow towlines.

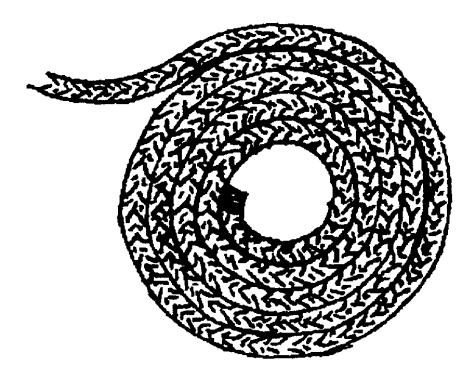
B.12. Coiling

The most common method of stowing the extra line on deck or on the dock after making fast to a cleat is to coil it.

B.13. Flemishing

Flemishing a line consists of coiling a line clockwise against the deck. It is used for appearance (eg: inspections, seaman-like appearance). (See Figure 7-8)





Flemishing a Line Figure 7-8

Chapter 7: Marlinespike Seamanship





Section C. Breaking Strength and Safe Working Load

Overview

Introduction

This section provides the necessary information to determine the breaking strength and safe working load of a line.

In this section

These items are discussed in this section:

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Breaking Strength and Safe Working Load of a Line	7-28
Breaking Strength and Safe Working Load for Shackles and	7-30
Hooks	
Considerations and Limitations	7-31



Breaking Strength and Safe Working Load of a Line

C.1. General

A line stretches as it takes on a load. It will continue to do so as tension increases until it reaches its breaking point. Then it will part and snap back. There have been many injuries and deaths caused by lines snapping when working under tension. Safe line handling is a combination of knowledge and skill. The ability to determine the breaking strength (BS) and safe working load (SWL) of a line is an important factor in safe line handling.

C.2. Breaking strength (BS)

The BS of a line is measured in the number of pounds of stress a line can take before it parts. It is a part of the technical information provided to a purchaser. The number comes from stress tests conducted by the manufacturer of the line and is an average of all the lines tested. This means, it is not accurate for any specific line. You must apply a safety factor to determine the SWL of a line.

C.3. Safe working load (SWL)

Line should be selected with its intended usage, or working load, in mind. A common seamanship practice says that the SWL of a line should be not more than one-fifth of its breaking strength, or that the BS should be five times the weight of the object attached to the rope. This five-to-one safety factor allows for sudden strains, shock loading, and normal deterioration as the line ages.

C.3.a. Various types of line

Figure 7-9 provides the breaking strength and safe working load in pounds for various types of line used on Coast Guard boats. In the table, each size of line is classified as "good," "average" or "poor."

The SWL and BS of the lines below were figured mathematically based on the circumference of each line. Line procured through government supply sources is measured in circumference. Commercially procured line, however, is measured in diameter. The formula for converting circumference to diameter and vice versa is contained in Appendix A. For simplicity, both the diameter and the circumference of the most commonly used Coast Guard lines are provided below.



			M	anila		Nylon (Double Braided)			
Size	Size	BS	SWL by Line Condition			BS	SWL I	by Line Co	ndition
Diam.	Cir.	lbs.	Good	Average	Poor	lbs.	Good	Average	Poor
5/8	2	3,600	720	360	240	9,000	3,000	2,250	1,500
11/16	21/2	5,625	1,123	562	375	14,062	4,687	3,515	2,343
7/8	23/4	6,804	1,360	680	454	17,010	5,670	4,242	2,835
1	3	8,100	1,620	810	540	20,250	6,750	5,062	3,375

		Polypropylene/Polyethylene					Polyester	(Dacron)	
Size	Size	BS	SWL by Line Condition			BS	SWL b	y Line Con	dition
Diam.	Cir.	lbs.	Good	ood Average Poor			Good	Average	Poor
5/8	2	5,040	1,008	840	630	7,200	2,400	1,800	1,200
11/16	21/2	7,875	1,575	1,312	840	11,250	3,750	2,812	1,875
7/8	23/4	9,525	1,905	1,588	1,190	13,608	4,536	3,402	2,268
1	3	11,340	2,268	1,890	1,417	16,200	5,400	4,050	2,700

Three-strand Nylon					
Size	Size	BS	SWL by Line Condition		
Diam.	Cir.	lbs.	Good	Average	Poor
5/8	2	10,300	3433	2575	1717
7/8	23/4	19,600	6533	4900	3267
1	3	25,000	8333	6250	4167

Minimum Breaking Strengths and Safe Working Loads for Natural and Synthetic Lines Figure 7-9

NOTE &

The only type of synthetic line authorized by the Coast Guard for towing is double braided nylon. The other lines listed in the table are for comparison purposes.

C.3.b. Three-strand nylon line

The Auxiliary may use three-strand nylon line for towing. Typical line size and average breaking strength are summarized below. The safe working load condition and specific values can be calculated as shown in Appendix A.



Breaking Strength and Safe Working load for Shackles and Hooks

C.4. General

Given a choice between the hardware breaking or the line parting, it is usually safer for the line to part. The BS of shackles is six times greater than their SWL. Figure 7-10 shows the sizes of shackles and hooks. The relationship is based on the SWL of hooks, shackles, and towlines. It is consistent with the general rule that you never use a shackle or hook with a SWL less than the SWL of the line being used.

C.5. Determining safety

To determine whether any of the shackles or hooks listed below are safe with a particular line, extract the SWL of the shackle or hook from the table. Next extract the SWL for the line. Finally, compare the two. The SWL of the shackle or hook should be equal to or greater than the SWL of the line.

Appendix A contains the formulas for computing the BS and SWL of line, hooks and shackles. The figures derived by using these formulas are only estimates of actual strengths for guidance purposes. Best judgement and experience must be applied when using these formulas.

Size	BS	SWL	Size	BS	SWL
Inches	lbs.	lbs.	Length	lbs.	lbs.
3/8	12,000	3,000	55/8	12,000	3,000
1/2	24,000	6,000	615/16	24,000	6,000
5/8	39,000	9,750	815/32	39,000	9,000

Recommended Shackles and Hooks to be Used With Coast Guard Authorized Towline Figure 7-10



Considerations and Limitations

C.6. General

Even though you may correctly determine the SWL of lines, shackles and hooks, there are many variables affecting the equipment. In actual use it is not always possible to operate within the SWL. Sometimes you can't match appropriate hardware with particular lines.

C.7. Keep alert

It is necessary for you to keep a constant eye on a line under stress. The unpredictable, unforeseen and often dangerous forces in the marine environment will catch you by surprise unless you are always on guard. By using good judgment you can usually make timely adjustments to correct for these adverse forces.

C.8. Stay within limits

Try to keep the tension on line and equipment well within their SWL. It is difficult to tell when the SWL is reached or surpassed. A sudden surging (pulling) of a towline may cause the tension on the line and hardware to approach their breaking points. This is when the danger of parting becomes a safety hazard.

C.9. Unknown BS and SWL

The moment you connect your towline to a distressed vessel's deck fittings, your entire towing system assumes an unknown BS and SWL factor. You often cannot get a reliable estimate of BS and SWL even when you can attach the proper equipment to the disabled craft. Because this is the weak link in towing, you must keep the towline and the boat in tow under constant observation.

C.10. Measure percentage of elongation

The device used to measure the percentage of elongation is called a Tattletale Cord or a Strain Gauge. A tattletale cord is a bight of heavy cord or light small stuff which is cut to a specific length depending on the type of synthetic line it is used with. The ends of the tattletale cord are secured at a specified distance apart on the line, again, depending on the type of synthetic line. As the line elongates under strain, the tattletale cord stretches with it. When the cord is drawn taut the line has reached the percent of critical strength for various synthetic lines, the length of tattletale cord used to measure this elongation and the distance the ends of the cord must be tied apart when secured on the line.



Dimensions for tattletale cords can be summarized as follows:

NOTE &

Navy studies have shown that tattletales will give warning for a line that has been shock loaded. Their use and position of placement on towlines is optional.

Type of Synthetic Line	Length of Tattletale in Inches	Distance Cord in Inches	Critical Stretch in Percent
Nylon (3 strand)	40	30	40
Nylon (double braided)	48	40	20
Nylon (plaited)	40	30	40
Polyester (3 strand)	34	34	20
Polypropylene (3 strand)	36	30	20



Section D. Knots and Splices

Overview

Introduction

This section details the procedures regarding the art of knots and splices.

In this section

These items are discussed in this section:

Topic	See Page
Estimating the Length of a Line	7-34
Breaking Strength	7-35
Basic Knots	7-36
Splices	7-54
Whipping	7-59
Mousing Hooks and Shackles	7-62



Estimating the Length of a Line

D.1. Procedure

Estimating a length of a line can be a useful skill. One method of doing so is as follows:

Step	Procedure
1	Hold the end of a length of line in one hand.
2	Reach across with your other hand and pull the line through the
	first hand, fully extending both arms from the shoulder.

The length of line from one hand to the other, across your chest, will be roughly six feet (one fathom). Actually, this distance will be closer to your height, but this measure is close enough for a rough and quick estimate of line needed.

If more line is needed, repeat the process keeping the first hand in place on the line as a marker until you have measured off the length of line required. For example, if you need 36' of line, you would repeat the procedure six times.



Breaking Strength

D.2. Knots and splices

Knots are used for pulling, holding, lifting, and lowering. When using line for these purposes it is often necessary to join two or more lines together. Knots and bends are used for temporary joining, and splices provide a permanent joining. In either case, the BS of the joined line is normally less than the BS of the separated lines.

The weakest point in a line is the knot or splice. They can reduce the BS of a line as much as 50 to 60 percent. A splice, however, is stronger than a knot. Figure 7-11 lists each of the commonly used knots and splices. It provides their percent of line BS lost and percent of line BS remaining.

Knots or Splice Remaining	Percent of Line Breaking Strength Lost	Percent of Line Breaking Strength Remaining
Square	46	54
Bowline	37	63
Two Bowlines		
(Eye in Eye)	43	57
Becket Bend	41	59
Double Becket Bend	41	59
Round Turn	30-35	65-70
Timber Hitch	30-35	65-70
Clove Hitch	40	60
Eye Splice	5-10	90-95
Short Splice	15	85

Percent of Line Breaking Strength Loss Figure 7-11



Basic Knots

D.3. General

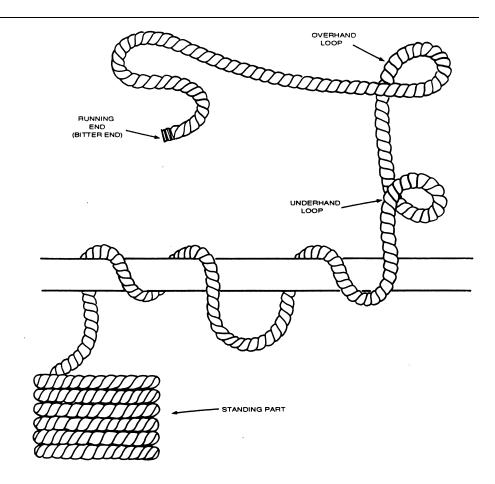
Knots are the intertwining of the parts of one or more lines to secure the lines to themselves, each other (bends), or other objects (hitches). Because knots decrease the strength of the line, they should always be treated as temporary. If you need something permanent, use a splice or seizing.

D.4. Definitions

In making knots and splices you must know the names for the parts of a line and the basic turns employed. Refer to figure 7-12 and 7-13 for an example of the following knots.

Knot	Description		
Bitter End	The running end or the free end of a line. It is the		
	end of the line that is worked with.		
Standing Part	The long unused or belayed end. The remaining part		
	of the line including the end that is not worked.		
Overhand Loop	A loop made in a line by crossing the bitter end over		
	the standing part.		
Underhand Loop	A loop made in the line by crossing the bitter end		
	under the standing part.		

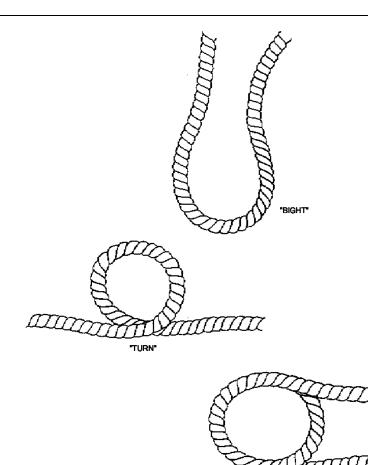




Basic Parts and Loops Figure 7-12

Knot Name	Description
Bight	A half loop formed by turning the line back on itself.
Turn	A single wind or bight of a rope, laid around a
	belaying-pin, post, bollard, or the like.
Round Turn	A complete turn or encircling of a line about an
	object, as opposed to a single turn.
•	





Bight and Turns Figure 7-13

"ROUND TURN"

D.5. Anatomy of a knot

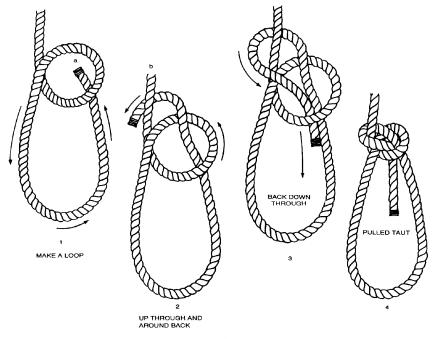
Good knots are easy to tie, easy to untie, and hold well. A good knot should not untie itself. A knot used to secure lines together is a bend. A knot used to secure a line to an object, such as a ring or eye, is a hitch. The knots listed below are those most commonly used in boat operations. Learn to tie them well, for the time may come when the skill to do so could decide the outcome of a mission.

D.5.a. Bowline

The bowline is a versatile knot. Use it anytime you need a temporary eye in the end of a line. It also works for tying two lines securely together, though there are better knots for this. An advantage of bowlines is that they do not slip or jam easily. Refer to figure 7-14 as you follow these steps below.



Step	Procedure
1	Make an overhand loop in the line the size of the eye desired.
2	Pass the bitter end up through the eye.
3	Bring the bitter end around the standing part and back down
	through the eye.
4	Pull the knot tight by holding the bitter end and the loop with
	one hand and pulling on the standing part with the other.



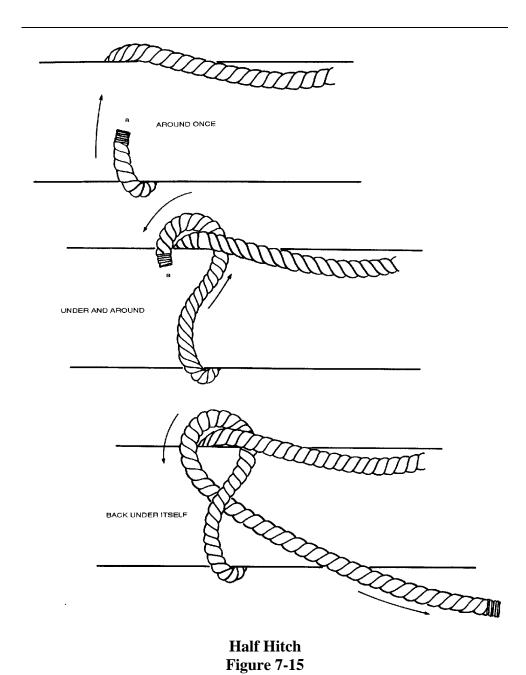
Bowline Figure 7-14

D.5.b. Half hitches

Hitches are used for temporarily securing a line to objects such as a ring or eye. One of their advantages is their ease in untying. The half hitch is the smallest and simplest hitch. Tie it only to objects having a right hand pull. Since a single half hitch may slip easily, use care in cases where it will encounter extreme stress. Refer to figure 7-15 as you follow the steps below.

Step	Procedure
1	Pass the line around the object.
2	Bring the working end "a" around the standing part and back
	under itself.





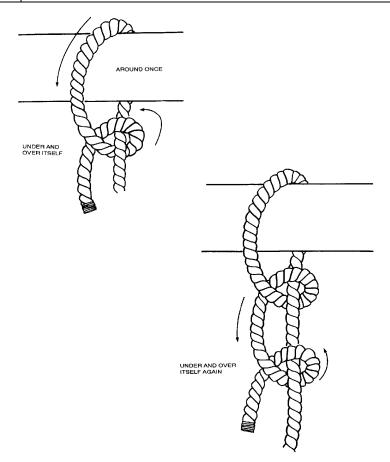
7-40



D.5.c. Two half hitches

To reinforce or strengthen a single half hitch, tie more. Two half hitches make a more reliable knot than a single half hitch. Use them to make the ends of a line fast around its own standing part. A round turn or two, secured with a couple of half hitches, is a quick way to secure a line to a pole or spar. Two half hitches are needed to secure a line at an angle where it might slide vertically or horizontally. Refer to figure 7-16 as you follow the steps below.

Step	Procedure
1	Take a turn around the object.
2	Bring the bitter end (running end) under and over the standing
	part and back under itself.
3	Continue by passing bitter end under and over the standing part
	and back under itself.



Two Half Hitches Figure 7-16

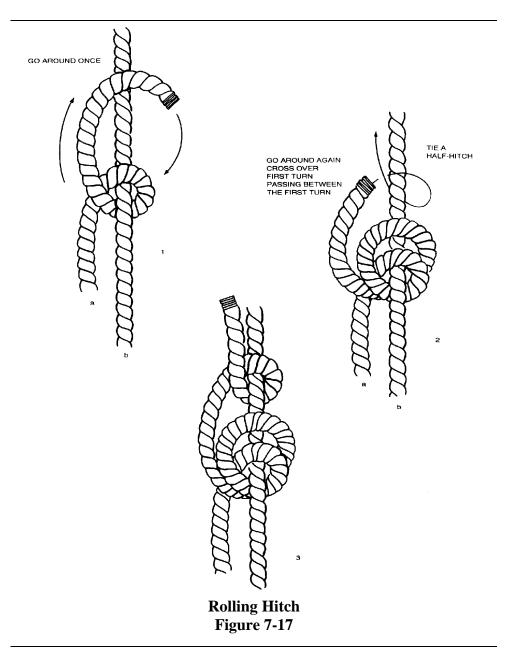


(Stopper)

D.5.d. Rolling hitch A rolling hitch is used to attach one line to another, where the second line is under a strain and cannot be bent. Refer to figure 7-17 as you follow the steps below.

Step	Procedure
1	With the bitter end "a" make a turn over and under the second
	line "b" and pass the link over itself.
2	Pass "a" over and under "b" again bringing "a" through the
	space between the two lines on the first turn.
3	Pull taut and make another turn with the bitter end "a" taking it
	over, then under, then back over itself.
4	Pull taut and tie a half hitch.



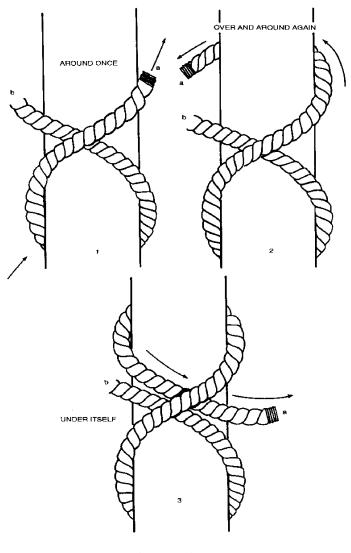


D.5.e. Clove hitch

A clove hitch is preferred for securing a heaving line to a towline. It is the best all-around knot for securing a line to a ring or spar. Correctly tied, a clove hitch will not jam or loosen. However, if it is not tied tight enough it may work itself out. Reinforce it with a half hitch. Refer to figure 7-18 as you follow the steps below.



Step	Procedure
1	Pass the bitter end "a" around the object so the first turn
	crosses the standing part.
2	Bring the bitter end "a" around again and pass it through itself.
3	Pull taut.
4	Reinforce by tying a half hitch.

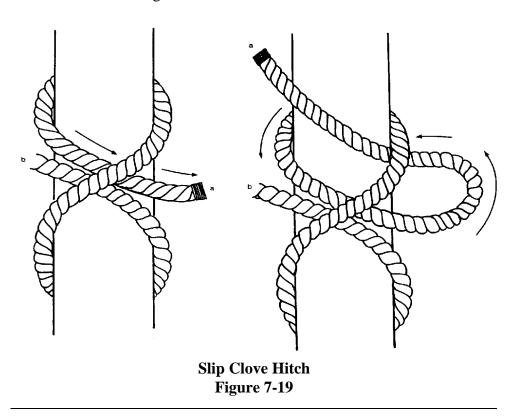


Clove Hitch Figure 7-18



D.5.f. Slip clove hitch

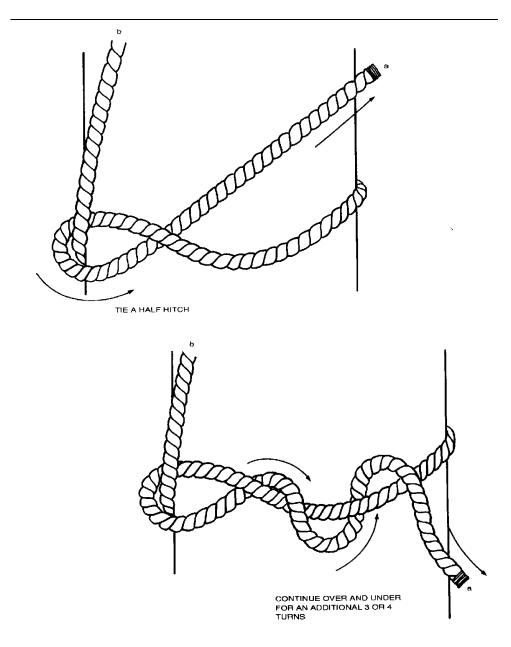
Use a slip clove hitch in lieu a clove. Tie it in the same manner as the clove hitch but finish it with a bight to allow for quick release. (See figure 7-19.) It is sometimes used for stowing lines and fenders. It should not be used when working with the line.



D.5.g. Timber hitch Timber hitches are used to secure a line to logs, spars, planks or other rough-surfaced material. Do not use it on pipes or other metal objects. Refer to figure 7-20 as you follow the steps below.

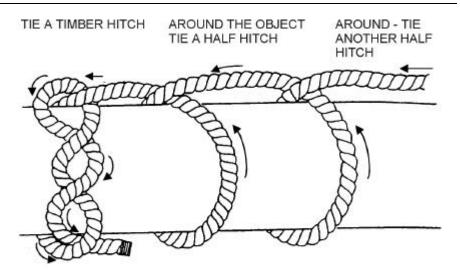
Step	Procedure
1	Tie a half hitch.
2	Continue taking the bitter end "a" over and under the standing
	part.
3	Pull the standing part taut.
4	You may add two half hitches for extra holding (See figure 7-
	21.) Unless you can slip the half hitch over the end of the
	object, tie it before making the timber hitch.





Timber Hitch Figure 7-20





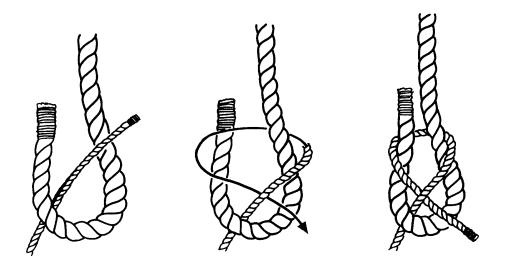
Timber Hitch with Two Half Hitches Figure 7-21

D.5.h. Single becket bend (sheet bend)

Lines can be lengthened by bending one to another using a becket bend. It is the best knot for connecting a line to an eye splice in another line. It can be readily taken apart even after being under a load. Single becket bends are used to join line of the same size or nearly the same size. It is intended to be temporary. Refer to figure 7-22 as you follow the steps below.

Step	Procedure
1	Form a bight in one of the lines to be joined together, line "a".
2	Pass the bitter end of the second line "b" up through the bight
	formed by the first line "a."
3	Wrap the end of line "b" around the bight in "a."
4	Pass the end of "b" under its own standing part.
5	Pull taut.

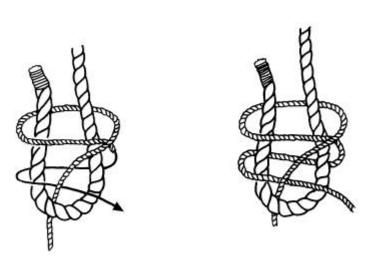




Single Becket/Sheet Bend Figure 7-22

D.5.i. Double becket bend (double sheet bend)

The double becket bend works for joining lines of unequal size. It is tied in the same manner as the single becket bend except for the following variation in step 4 above: Pass line "b" around and under its standing part twice. (See figure 7-23.)



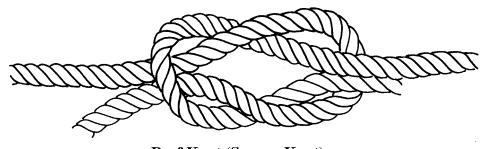
Double Becket/Sheet Bend Figure 7-23



D.5.j. Reef knot (square knot)

Called a square knot by Boy Scouts, the reef knot is one of the most commonly used knots in marlinespike seamanship. Reef knots are rarely used on small boats because they jam badly under strain. Also, reef knots do not effectively hold lines of different sizes or materials. Reef knots are best used to finish securing laces (canvas cover, awning, sail to a gaff, etc.), temporary whippings, and other small stuff. Refer to figure 7-24 while tying this knot.

Step	Procedure
1	Tie a single overhand knot.
2	Tie a second overhand knot on top so it mirrors (right and left
	reversed) the first one. The ends should come out together.
3	Draw tight.



Reef Knot (Square Knot) Figure 7-24

D.5.k. The monkey's fist

Because some lines, such as towlines, are too heavy and awkward to throw any distance, a heaving line, with a monkey's fist tied on one end, is used. On Coast Guard boats, heaving lines are normally 75 to 100 feet of cotton line with a weighted core. Refer to figure 7-25 while tying this knot.

Step	Procedure
1	Lay a bight of the line across the fingers of the left hand, about
	three and one-half feet from the end, holding the standing part
	with the left thumb.
2	With your fingers separated, take three turns around them.
3	Next take three turns around the first three and at right angles
	to them.
4	Take the knot off your fingers and take an additional three
	turns around the second three and inside the first three.



Step	Procedure
5	Take additional care at this step. Place the core weight into the
	knot and tighten it down carefully.
6	After tightening, there should be about 18 inches of line left on
	the bitter end. This can be brought up and seized alongside to
	the standing part.

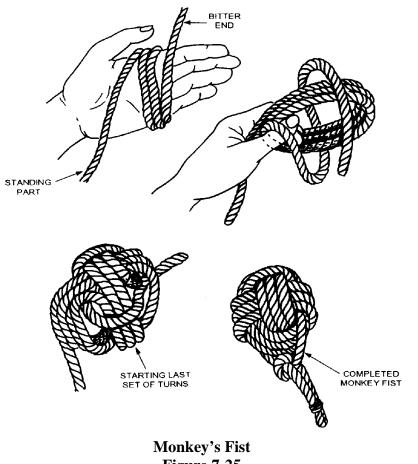


Figure 7-25

D.5.1. Figure eight (stopper)

A figure eight knot is an overhand knot with an extra twist. It will prevent the end of a line from feeding through a block or fairlead when heavy loads are involved. It is also easier to untie and does not jam as hard as the over hand knot. (See figure 7-26.)



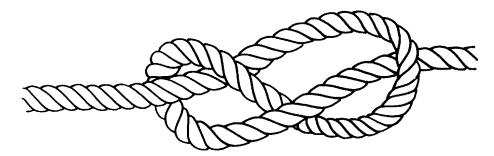
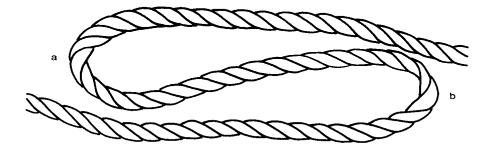
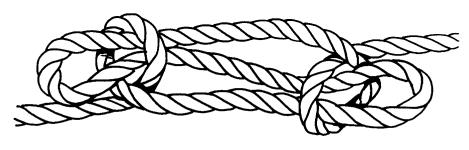


Figure Eight Knot Figure 7-26

D.5.m. Sheepshank

This hitch is used for temporarily shortening a piece of line. It consists of two bights of line, side-by-side, with a half hitch at either end. (See figure 7-27.)





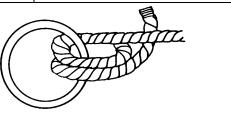
Sheepshank Figure 7-27

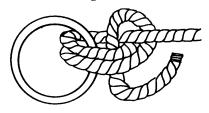
D.5.n. Fisherman's or anchor bend

This bend is used to secure a line to a ring in an anchor or mooring buoy. It can also be tied around a spar. (See figure 7-28.)



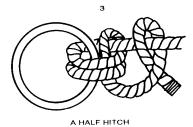
Step	Procedure
1	Pass the bitter end through the ring and around twice creating
	two loops spiraling downward
2	Wrap the bitter end up around the standing end and pass back
	through the loops at the top.
3	Tie a half hitch.
4	Pull taut.

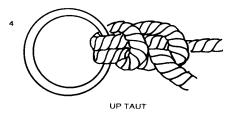




AROUND TWICE

BACK THROUGH





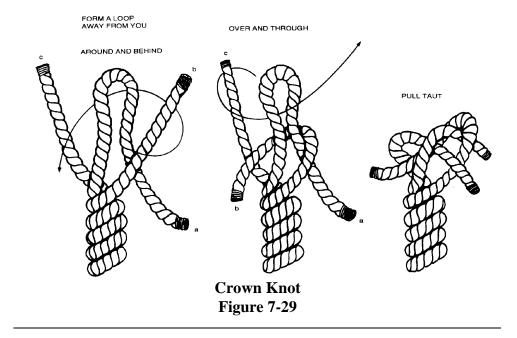
Fisherman's or Anchor Bend Figure 7-28

D.5.o. Crown knot

A crown knot may be used to prevent an unwhipped line from unlaying. (See figure 7-29.)



Step	Procedure
1	Unlay the strands of the line about 12".
2	Separate the strands and hold them up with the middle strand
	facing you.
3	Bend the middle strand "a" away from you and form a loop.
4	Bring the right strand "b" around behind the loop, placing it
	between strand "c".
5	Bring strand "c" over strand "b" and through the loop formed
	by strand "a".
6	Pull taut by heaving on each of the three strands.
7	Lay the back splice by tucking each strand back up the line.
	The splicing is done as if making an eye splice.





Splices

D.6. General

Splices make a more permanent joining of two lines or two parts of a line. It is done by unlaying the strands or parts of the line(s) to be spliced and then putting the strands or parts back together to form a new union. The type of splice used depends on the type of joint and the type of line. On Coast Guard boats the most common splices are eye splices at the working end of the towline, side lines, and mooring lines. Because double splices in braided nylon is the accepted line for towlines, eye splices in double braid will be shown. For those people who use three strand nylon for mooring lines, three strand eye splices will be illustrated. Additionally, directions for three strand back slices are given. They are a handy way for finishing off the ends of the lines on fenders and three strand heaving lines.

D.6.a. Eye splice in three strand plaid laid line

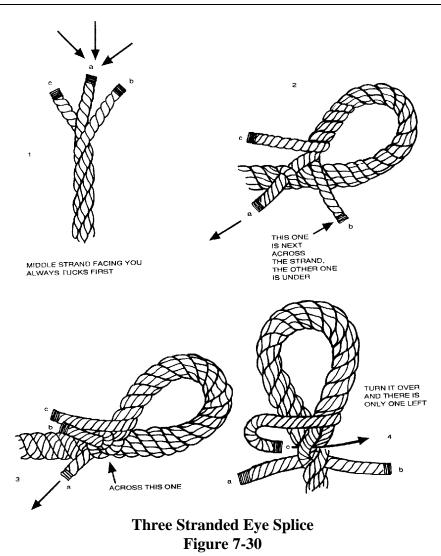
The eye splice makes a permanent loop (the eye) in the end of a line. Refer to figure 7-30 as you follow the steps below.

NOTE &

Always tuck the
middle strand first
and keep the right-
hand strand of the
side of the line that
is facing toward
you. All tucks are
made from outboard
toward you.

Step	Procedure
1	Unlay the strands of the line about 12".
2	Make a bight the size of the eye required.
3	Hold the strands up so the middle strand is facing you.
4	Tuck the middle strand "a."
5	Cross strand "b" over the strand just tucked and then under the
	strand just below it.
6	Turn the entire eye splice over and tuck strand "c."
7	Pull all strands tight.
8	Pass each strand over the adjacent strand and under the next strand until there are three tucks in each strand (Synthetic line requires an additional tuck).





D.6.b. Back splice in three strand plain laid line

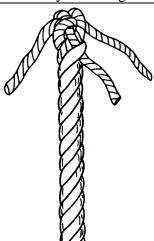
Use a back splice to finish off the end of a line. On Coast Guard boats it can be used on the ends of fender lines. Start with unlaying the strands at the end. Then bend them back on the line, and then interweave them back through the strands of the standing part. The procedure for making a back splice are as follows: (See figure 7-31.)

Step	Procedure
1	Begin the back splice by tying a crown knot. Each strand goes
	under and out from its neighbor in the direction of the lay.
2	Pass each strand under itself, just beneath the crown knot. Do
	not pull these first tucks too tight.



Step	Procedure
3	Proceed with three more rounds of tucks - over one, under
	one, as in an eye splice.
4	If preferred, it can finished by trimming the ends of the strands.







Back Splice (Three Strand) Figure 7-31

D.6.c. Short splice

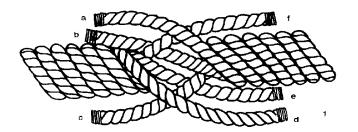
A short splice is used to permanently connect two ends of a line. It is important to note that a short splice is never used in a line that must pass over a pulley or sheeve. The procedure for making a short splice are as follows: (See figure 7-32.)

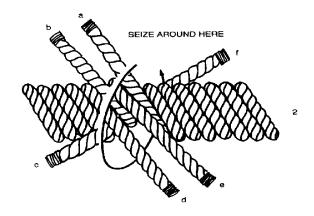
NOTE &

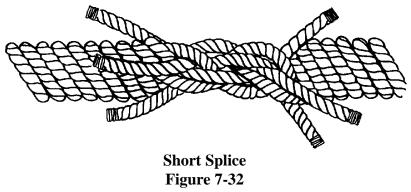
If desired, taper the short splice in the same manner as the eye splice.

Step	Procedure
1	Unlay the strands of the lines to be spliced, about 12".
2	Bring the ends together by alternating strands.
3	Slide the two ends together, that is butt them and temporarily seize them with sail twin or tape.
4	Tuck each strand over and under three times, the same way as in eye splicing. (Synthetic line requires an additional tuck.)
5	Remove the seizing.











D.6.d. Eye splice in double braid line

Splicing double braid entails pulling the core out of the cover and then putting the line back together to make the splice. The basic principle for putting it back together is:

- 1. The cover goes into the core.
- 2. Then the core goes back into the cover.

Splicing double braid requires the use of a special fid, or similar tool. The most common type is a bllet-nosed, hollow, tubular device. Use it with a proper sized line. This type of fid requires a "pusher" which resembles a long, blunt-pointed ice pick. For instructions on splicing double braided nylon, see Appendix 7-D.



Whipping

D.7. General

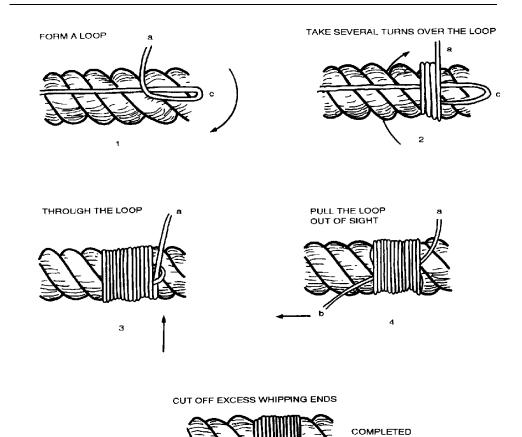
The end of a cut line will unravel and fray if not secured with a whipping or back-spliced. Whippings may be permanent or temporary.

D.8. Temporary whipping

Sometimes called the common whipping, temporary whippings make temporary repairs and secure strands of lines while splicing. They are not very durable and easily unravel if snagged. They are normally done using sail twine, although almost any small stuff will do. The procedures below instruct how to make temporary whipping.

Step	Procedure
1	Cut a piece of sail twine or small stuff, in length about ten times
	the circumference of the line being seized.
2	Lay the sail twine or small stuff alongside the line to be
	whipped (See figure 7-33.)
3	Form an overhand loop in the sail twine or small stuff such that
	the loop extends about ½" beyond the end.
4	Holding end "a," make a series of turns over the loop toward
	the bitter end of the line. Make enough so the length of the
	turns are about equal to the diameter of the line.
5	Slip end "a" through the loop "c."
6	Secure by pulling loop end from sight by pulling on "b."
7	Cut off excess whipping ends or secure them by tying them
	together with a reef or square knot.





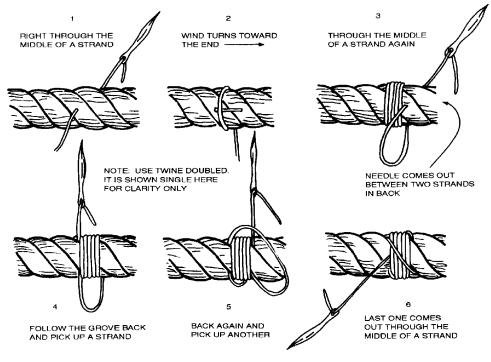
Temporary Whipping Figure 7-33

D.9. Permanent whipping

Permanent whippings are made to last. To make one, take several wraps around the line using shot line or waxed nylon. Then sew the ends of the whipping line across the whipping and through the line. (See figure 7-34.)



Step	Procedure
1	Cut enough of the whipping line to allow for 15 to 20 wraps,
	with at least a foot of line left over.
2	Secure the whipping line by sewing it through the line. If you
	want, you can add strength by sewing through more than once.
3	Wind the whipping line around the line 15 to 20 times, working
	toward the end of the line. Make sure the body of the
	whipping covers the secured end of the whipping line.
4	Secure the whipping by sewing through the line. Then bring
	the line across the whipping and sewing it through the line. Do
	this three or more times, depending on the size of the line.
5	Finish the whipping by sewing through the line a couple more
	times and cutting the whipping line off close. A pull on the line
	will pull the end of the whipping line inside, hiding it from
	view.



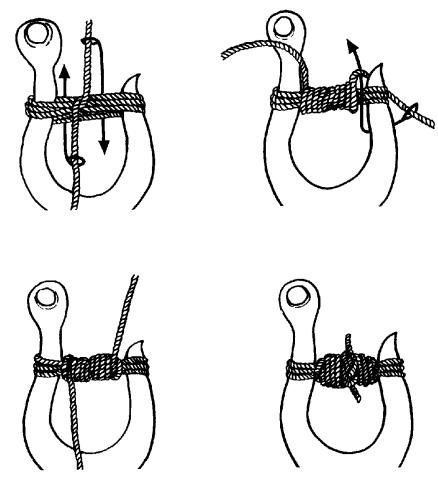
Permanent Whipping Figure 7-34



Mousing Hooks and Shackles

D.10 Hooks

A hook is moused to keep slings and straps from slipping out or off the hooks. This is accomplished by either mechanical means or by seizing the hook, using seizing wire or small stuff, from opposite sides. (See figure 7-35.)



Mousing a Hook Figure 7-35



D.11. Shackles

Shackles are moused to prevent the pin from backing out. This is usually done on screw pin shackles. Mousing is accomplished by taking several turns, using seizing wire or small stuff, through the pin eye and around the shackle itself in such a way so the pin cannot turn.

Chapter 7: Marlinespike Seamanship





Section E. Deck Fittings and Line Handling

Overview

Introduction

This section explains the procedures for securing lines to the various types of deck fittings.

In this section

These items are discussed in this section:

Topic	See Page
Deck Fittings	7-66
Line Handling	7-67



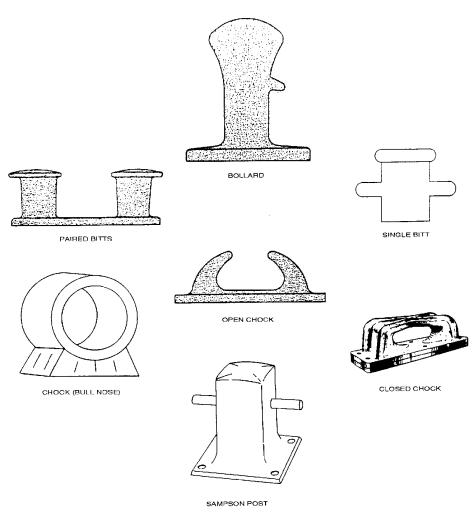
Deck Fittings

E.1. General

Deck fittings are attachments or securing points for lines. They permit easy handling and reduce wear and friction on lines.

E.2. Types of fittings

There are three basic types of deck fittings: Bitts, cleats, and chocks. Several types of deck fittings are shown in figure 7-36.



Types of Deck Fittings Figure 7-36



Line Handling

E.3. General

Most Coast Guard standard boats have a towing bitt and a bow bitt. You find cleats on the decks next to the gunwales on each side of a boat used with bitts and cleats to help prevent chafing of the line. The chock provides a smooth surface for the line to run over or through. Because of the difference in the structural design of nonstandard boats, the strength of their deck fittings will vary widely.

E.4. Using proper sized line

The size of the deck hardware depends on the size of line to be used for mooring docking and towing. Cleats are sized by length, and the rule of thumb is the line should be 1/16" in diameter for each inch of cleat ($^3/_8$ " line = 6" cleat, $^1/_2$ "line = 8" cleat.

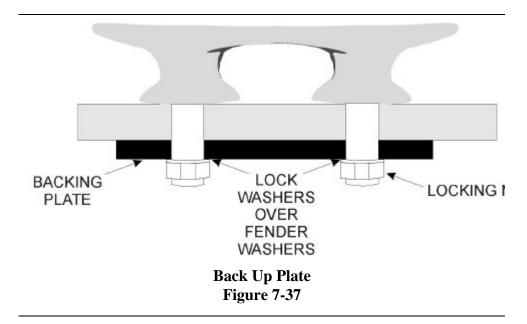
NOTE &

On Auxiliary operational facilities (as a rule of thumb) no tow should be attempted with smaller than $^3/_8$ " line; therefore, the smallest size cleat on a facility should be 6".

E.5. Back up plates

All deck hardware that is used for towing should have back up plates to distribute the load over a wide area (See figure 7-37). The back up plate can be made of pressure treated hardwood or exterior grade plywood, at least twice as thick as the largest bolt diameter. Use bolts, not screws. A flat washer and a lock washer must be used with the bolt. The flat washer is three times the bolt diameter. If metal is used, the thickness should be at least the same as the bold diameter. The use of soft aluminum is not recommended. Bedding compound should be used in all installations.





E.6. Securing a line to a bitt

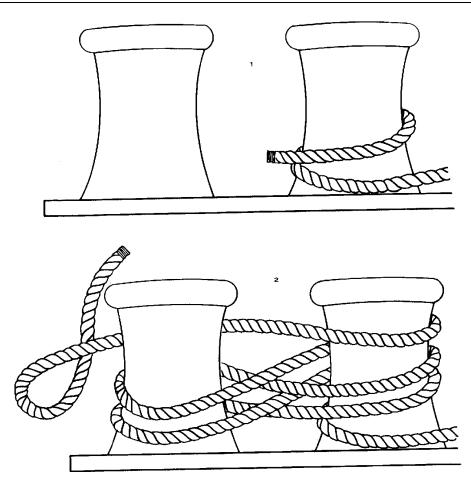
The procedures below describe how to secure a line to a bitt:

NOTE &

Avoid the use of half-hitches, weather hitches, and lock hitches on standard boats.

Step	Procedure
1	Make a complete turn around the near horn (See figure 7-38).
2	Make several figure eights around both horns. (Size of line and cleats may restrict the number of turns. Minimum of 3 turns is the standard).
3	Finish off with a round turn.





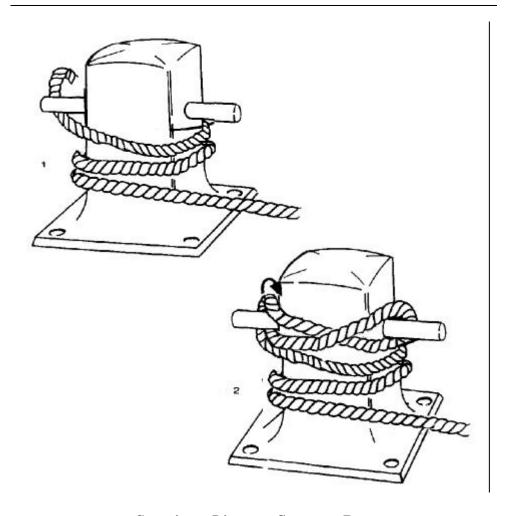
Securing a Line to a Bitt Figure 7-38

E.7. Securing a line to a sampson post

A sampson post is a vertical timber or king post on the forward deck of a boat. They are used as a bow cleat or bitt.

Step	Procedure
1	Make a complete turn around the base of the sampson post (See
	figure 7-39).
2	Form several figure eights around the horns of the sampson post.
	(Standard is 3 turns.)





Securing a Line to a Sampson Post

(figure does not show extra figure eights)

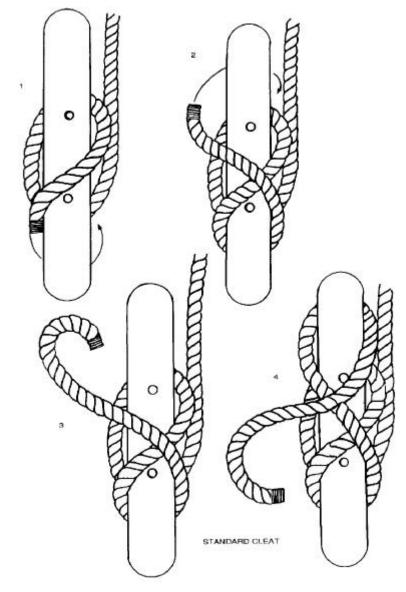
Figure 7-39

E.8. Securing a line to a standard cleat

The procedures below describe how to secure a line to a standard cleat (See figure 40).



Step	Procedure
1	Make a complete turn around the cleat.
2	Lead the line over the top of the cleat and around the horn to
	form a figure eight.
3	If possible, make two more figure eights.



Securing a Line to a Standard Cleat (figure does not show the extra figure eights)

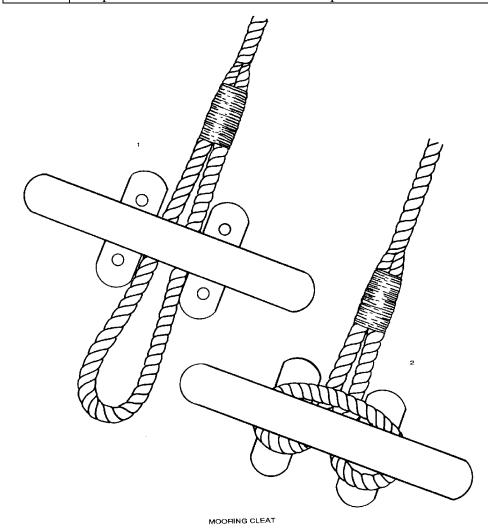
Figure 7-40



E.9. Securing a line to a mooring cleat

The procedures below describe how to secure a line to a mooring cleat (See figure 41).

Step	Procedure
1	Feed the eye of the line through the opening.
2	Loop the line back over both horns and pull the line taut.



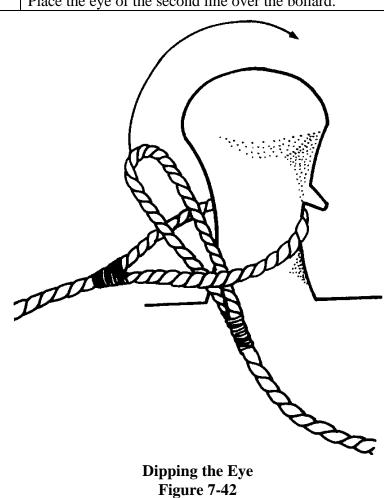
Securing a Line to a Mooring Cleat Figure 7-41



E.10. Dipping the eye

When two lines with eye splices are placed on a bollard, it may not be possible to remove the bottom line until the top line is removed. By dipping the eye, both lines can be placed for easy removal (See figure 42).

Step	Procedure
1	Place the eye of one mooring line over the bollard.
2	Take the eye of the second line up through the eye of the first
	line.
3	Place the eye of the second line over the bollard.





E.11. Securing a towline

The towline is a potential danger to anyone near it. Towlines should be made up so slack can be paid out at any time or so the line can be slipped (cast off) in an emergency. Procedures for securing the towlines on standard Coast Guard boats may be found in their respective operator manuals. Additional information on the use of towlines is in Chapter 17.



Appendix 7-A

Estimating the Breaking Strength and Safe Working Load of Lines

General

The following paragraphs provide a detailed explanation of how to estimate the breaking strengths of particular types of lines. It also explains how to use this number to figure the safe working load. Each type of line has a different breaking strength, and a different safe working load.

Breaking strength of natural line

The estimated breaking strength (BS) of a piece of manila line can be found by squaring the circumference (C) of the line and then multiplying that number by 900 pounds. The formula for this is: $BS = C2 \times 900$ pounds.

Example:

Suppose the circumference of a piece of manila line is 3 inches. The breaking strength of that line can be determined as follows:

Step	Procedure
1	$BS = C2 \times 900 \text{ pounds}$
2	$C2 = 3 \times 3 = 9$
3	$BS = 9 \times 900 \text{ pounds}$
4	BS = 8100 pounds

Breaking strength of synthetic line

Use the same basic formula to estimate the breaking strength of synthetic lines by the addition of one more step. Because synthetic lines are stronger than manila line, the number of pounds representing their breaking strengths is multiplied by their comparison factors (CF).

Comparison factors

Comparison factors are based on the strength of a synthetic line in comparison to natural manila line. The comparison factors given in Table A-1 reveal that synthetic line is stronger than manila line.



Line Name	CF to Manila Line
Polypropylene	1.4
Polyethylene	1.4
Polyester (Dacron)	2.0
Nylon	2.5

Comparison Factors (CF) for Synthetic Line Table A-1

Estimating BS of synthetic line

The formula for estimating the breaking strength of synthetic line is $BS = C2 \times 900 \times CF$.

Step	Procedure
1	$BS = C2 \times 900 \times CF$
2	$C2 = 3 \times 3 = 9$
3	$BS = 9 \times 900 \text{ pounds } \times CF$
4	BS = 8100 pounds x CF
5	CF = 2.0 for polyester (dacron) line (taken from Table A-1)
6	BS = 8100 pounds x 2
7	BS = 16,200 pounds

Safe working load of natural and synthetic line Breaking strength is the tension, measured in pounds, a line can absorb before it breaks. To be on the safe side you do not want to stress a line anywhere near its breaking point. The safe working load (SWL) of the line is considerably less than its breaking strength.

As a line wears, stretches or is spliced, its breaking strength decreases. Quite naturally, this also causes a decrease in the safe working load of the line. By making a quick inspection of a piece of line and determining whether it is in good, average or poor condition you can calculate an estimate of the safe working load of a line. Once the condition of the line is determined enter Table A-2 and apply the safety factor (SF) into its breaking strength using the formula: SWL = BS/SF.



Condition	Manila	Nylon & Polyester	Polypropylene Polyethylene
Good	5	3	5
Average	10	4	6
Poor	15	6	8

Safety Factors for Natural and Synthetic Lines Table A-2

SWL of manila line

Figure the safe working load of a 3 inch manila line, in average condition, with a breaking strength of 8100 lbs.

Step	Procedure
1	Determine the condition of the line and extract the appropriate
	safety factor from Table A-2. In this case $SF = 10$.
2	SWL = BS/SF
3	SWL = 8100 lbs./10
4	SWL = 810 lbs.

SWL of polyester line

Figure the safe working load of a 2 inch polyester (dacron) line in poor condition:

Step	Procedure
1	$BS = C2 \times 900 \text{ pounds } \times CF$
2	$C2 = 2 \times 2 = 4$
3	$BS = 4 \times 900 \times CF$
4	BS = 3600 x CF
5	CF = 2 (Table A-1)
6	$BS = 3600 \times 2$
7	BS = 7200 pounds

Determining the condition of line

Determine condition of line and extract the appropriate safety factor from Table A-2:



Step	Procedure
1	SF = 6
2	SWL = BS/SF
3	SWL = 7200/6
4	SWL = 1200 pounds

Determining the diameter of a line

The following formulas will help when determining the diameter of a line using two methods:

- Converting diameter to circumference
- Converting circumference to diameter

Convert diameter to circumference

Some sources of supply measure line by diameter. Sailors measure and refer to line by circumference. The formula to convert diameter to circumference is $C = D \times 3.1416$.

Convert a diameter of ½ inch into circumference:

 $C = \frac{1}{2}$ " x 3.1416

C = 1.5708"

 $C = 1\frac{1}{2}$ " (rounded off)

Convert circumference to diameter

For converting circumference to diameter, you just turn the formula over; use D = C/3.1416.

Convert a circumference of 3" into a diameter.

D = 3''/3.1416

D = .955"

D = 1" (rounded off)



Appendix 7-B

Estimating the Safe Working Load of Shackles

General

There is no formula to determine the breaking strength of shackles. Use the manufacturers specifications. Bear in mind that damaged, bent or severely rusted shackles are unusable.

Determining the SWL

To determine the SWL of a shackle first measure the diameter (D) of the shackle at the point on the shackle shown in Figure 1-28. Technically, this is referred to as the Wire Diameter. The SWL of a shackle, in tons, is calculated by using the formula $SWL = 3 \times D2$.

Use 3 tons as a constant and apply it to all usable shackles.

Calculate the SWL of a shackle with a 2 inch wire diameter as follows:

Step	Procedure
1	$SWL = 3 tons \times D2$
2	$D2 = 2 \times 2 = 4$
3	SWL = 3 tons x 4
4	SWL = 12 tons



Appendix 7-C

Estimating the Safe Working Load of Hooks

General

Like shackles, the breaking strength of hooks is found in the manufacturers specifications or in Table 1-3. Damaged, bent, or severely rusted hooks are unusable. The condition of a hook is either usable or unusable.

Determining the SWL

To determine the SWL of a hook measure the diameter (D).

Use a "2/3" of a ton as a constant factor and apply it to all usable hooks by using the formula SWL = 2/3 ton x D2.

Calculate the safe working load of a hook with a 2 inch diameter as follows:

Step	Procedure
1	SWL = 2/3 ton x D2
2	$D2 = 2 \times 2 = 4 \text{ or } 4/1$
3	SWL = 2/3 ton x 4/1
4	SWL = 8/3 or 22/3 ton
5	SWL = 2.66 tons



Appendix 7-D

Eye Splice in Double Braid Line

The following series of steps (which is under copyright by Samson Ocean Systems, Inc.) is reprinted here by permission. It shows the specific steps needed to accomplish the splice for Samson double braided line. Other manufacturers of double braided line provide splicing instructions. Request specific information for splicing from the appropriate manufacturer.

Standard Eye - NEW ROPE

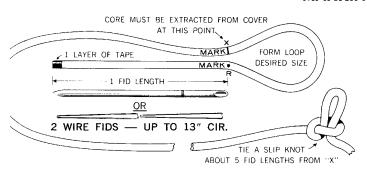


This Samson Eye Splice is for new rope only. It retains approximately 90% of the average new rope strength.

For splicing used rope, start with Step 1B, on Page 29.

MARKING THE MEASUREMENTS . . . STEP





On rope over 1" diameter, it is often easier to pass a spike or similar object through the rope instead of tying a slipknot.

Tape end to be spliced with one thin layer of tape. Then, measure one tubular fid length (2 wire fid lengths because wire fid is $\frac{1}{2}$ size) from end of rope and mark. This is Point R (Reference).

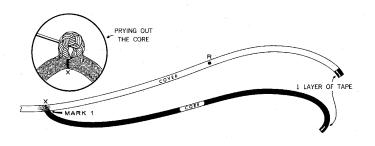
From R form a loop the size of the eye desired and mark. This is Point X where you extract core from inside the cover. If using a thimble, form the loop around the thimble. (See Special Tips, for more information on installing a thimble).

Tie a tight slip knot approximately five fid lengths from X. THIS MUST BE DONE.

In the event you require the rope with the finished splice(s) to be a certain overall length, refer to Special Tips.



STEP 2A ... NEW ROPE: EXTRACTING THE CORE



Bend rope sharply at X. With the pusher or any sharp tool such as an ice pick, awl, or marlin spike, spread the cover strands to expose core. First pry, then, pull the core completely out of cover from X to the taped end of the rope. Put one layer only of tape on end of core.

Note: DO NOT pull cover strands away from rope when spreading cover as this will distort rope unnecessarily.

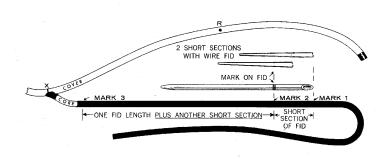
To assure correct positioning of Mark #1 do the following.

Holding the exposed core, slide cover as far back towards the tightly tied slipknot as you can. Then, firmly smooth the cover back from the slip knot towards taped end. Smooth again until all cover slack is removed.

Then, mark the core where it comes out of the cover.

THIS IS MARK #1.

NEW ROPE: MARKING THE CORE ... STEP 3A



Again slide cover toward slipknot to expose more core.

From Mark #1, measure along core towards X a distance equal to the short section of tubular fid (2 short sections with wire fid) and make two heavy marks.

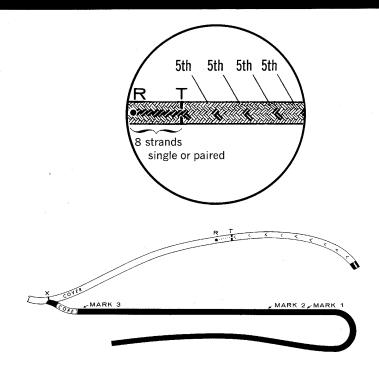
THIS IS MARK #2.

From Mark #2 measure in the same direction one fid length plus another short section of the fid. (With wire fid, double measurements) make 3 heavy marks.

THIS IS MARK #3.



$_{ ext{step}}$ 4A . . . new rope: marking the cover for tapering



Note nature of cover braid. It is made up of strands — either one or two (pair). By inspection you can see half the strands revolve to the right around rope and half revolve to the left.

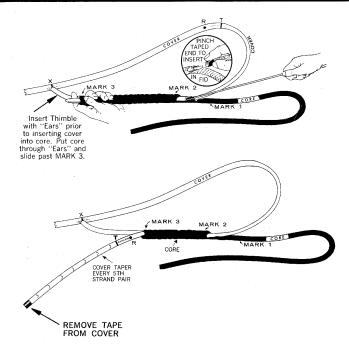
Beginning at "R" and working toward taped end of the cover, count 8 consecutive strands (single or pairs) which revolve to the right (or left). MARK THE 8th STRAND.

This is Point T. (See Insert). Make Mark T go completely around cover.

Starting at T and working toward the taped cover end, count and mark every fifth right and left strand (single or paired) until you have progressed down to end of taped cover.



NEW ROPE: PUTTING THE COVER INSIDE CORE . . . STEP 5A



Insert fid into core at Mark #2. Slide it through and out at Mark #3.

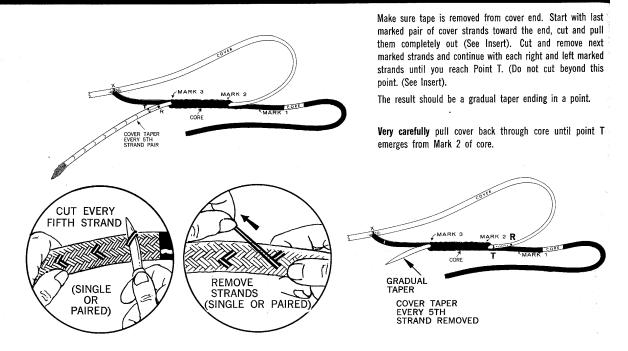
Add extra tape to cover end; then jam it tightly into the hollow end of fid (See Insert). Hold core lightly at Mark #3, place pusher joint into taped end, and push fid and cover through from Mark #2 and out at Mark #3.

With wire fid first press prongs into cover, then tape over (see "Tools Needed"). Then after fid is on, milk braid over fid while pulling fid through from Mark #2 to Mark #3.

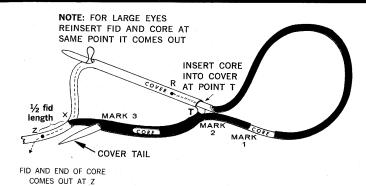
Take the fid off the cover. Continue pulling cover tail through the core until Mark R on the cover emerges from Mark #3. Then remove tape from end of cover.



STEP 6A ... NEW ROPE: PERFORMING THE TAPER



NEW ROPE: REINSERTING THE CORE INTO COVER ... STEP 7A



From point X on cover measure approximately $\frac{1}{2}$ fid length toward slip knot on rope and mark this as point Z.

You are now ready to put core back into cover from T to Z. Insert fid at T, jam the taped core end tightly into end of fid. With pusher, push fid and core through cover "tunnel", past X, to, and through cover at Z.

When using wire fid, attach fid to taped core. After fid is, on, milk braid over fid while pulling through from T to Z.

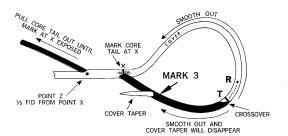
When pushing fid past X to Z make sure fid does not catch any internal core strands.

NOTE:

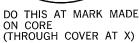
Depending on eye size, fid may not be long enough to reach from T to Z in one pass. If not, bring fid out through cover, pull core through and reinsert fid into exact hole it came out of. Do this as many times as needed to reach Z.

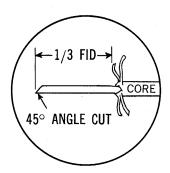


STEP 8A ... NEW ROPE: MARKING THE REDUCED VOLUME TAIL CORE









Alternately pull on core tail at Z, then pull on tapered cover at Mark 3. The crossover should be tightened until crossover is approximately equal to diameter of rope.

Smooth out cover of eye completely, from crossover (T) toward \boldsymbol{X} , to get all slack out of eye area.

MARK CORE TAIL THROUGH COVER AT POINT X.

Pull core tail out until mark on core just made is exposed at ${\sf Z}.$

Reduce core volume at this point by cutting and removing one strand at each group, progressing around the circumference of the rope (see insert).

Measure 1/3 fid from start of reduction cuts (mark) toward end and mark. Cut off remaining tail at this point. Make cut on a 45° angle to prevent a blunt end (see insert).

With one hand, hold crossover - MARK T.

Smooth cover section of eye out firmly and completely from crossover toward X; Reduced volume core tail should disappear into cover at Z.

Smooth out core section from crossover towards MARK 3 and cover taper will disappear into core.

BEGINNING AT SLIPKNOT, "MILK" COVER

BY SLIDING HAND TOWARD LOOP

29-----

FIG. 1

FIG. 2



NEW ROPE: BURYING THE EXPOSED CORE . . . STEP



Continue milking until all cover slack between knot and throat of eye has been removed.

hand and then firmly smooth cover slack (female side of eye) with other hand towards throat (X). Repeat as necessary

until bunching disappears.

Before burying the cover over the crossover:

- A. Anchor loop of slip-knot by tying it to stationary object before starting to bury. You can then use both hands and weight of body to more easily bury cover over core and crossover. (See Fig. 1 & 2).
- B. Holding the crossover tightly milk all the excess cover from R to X.

Flex and loosen the rope at the crossover point during the final burying process. Hammering cover at point X will help loosen strands.

With larger ropes it is helpful to securely anchor slip-knot, attach a small line to the braided core at the crossover and mechanically apply tension with either a block and tackle, capstan, come-a-long, or power winch. Tension will reduce diameter of core and crossover for easier burying. (See Fig. 2).

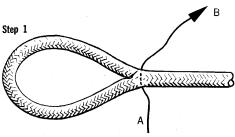
. NEW ROPE: FINISHING THE SPLICE WITH LOCK-STITCH

FIRMLY SECURED

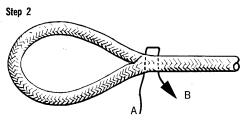
MILK COVER UNTIL CORE

BURY TO

MARK R



Pass stitching through spliced area near throat of eye as shown.



Re-insert as shown pulling snug but not tight.

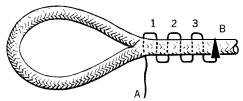
Stitch locking is advantageous on splices to prevent no-load opening due to mishandling.

Material Required — About one (1) fid length of Nylon or Polyester Whipping Twine approximately the same size of the strands in the size rope you are stitch locking. The same strands cut from the rope you are stitch locking may also be used.



NEW ROPE: LOCK-STITCH PROCEDURE . . . STEP 11A

Step 3



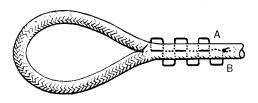
Continue to re-insert as shown until you have at least three (3) complete stitches.

Step 4

After completing Step #3, rotate spliced part of rope 90° and re-insert end "A" into splice area in the same fashion as in steps #1, #2, and #3. The splice will now be stitched on two planes perpendicular to each other. Make sure you do not pull stitching too tight.



Configuration of cross section after completing Step #4.



Step 5

After stitching at least three (3) complete stitches as in step #3, extract two ends A & B together through the same opening in the braid. Tie them together with a square knot and re-insert back into braid between cover and core.

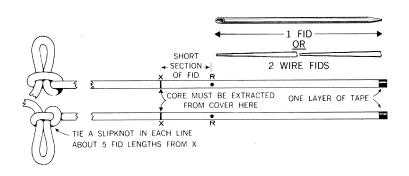


End-For-End Double Braid



The Samson Standard End-for-End Splice can be performed on new and used rope. This is an all-purpose splice technique designed for people who generally splice used rope as frequently as new rope. It retains up to 85% of average new rope strength and in used rope up to 85% of the remaining used rope strength.

Before splicing used rope, study the Special Tips shown on Page 7.

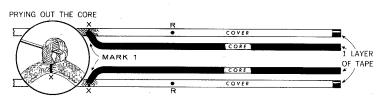


Tape the end of each rope with one thin layer of tape. Lay two ropes to be spliced side by side and measure one tubular fid length (2 wire fid lengths because wire fid is $\frac{1}{2}$ size) from end of each rope and make a mark. This is Point R (Reference).

From R measure one short fid section length as scribed on the fid; then, mark again. This is Point X where you should extract core from inside cover. Be sure both ropes are identically marked.

Tie a tight slipknot approximately 5 fid lengths from X. If you require the rope with the finished splice to be a certain overall length, refer to Special Tips Page 5.

EXTRACTING THE CORES. . . STEP 2



DO NOT PULL COVER STRANDS AWAY FROM ROPE AS THIS WILL DISTORT COVER UNNECESSARILY

Bend rope sharply at X. With the pusher or any sharp tool such as an ice pick, awl, or marlin spike, spread cover strands to expose core. First pry; then, pull core completely out of cover from X to the end of rope. Put one layer only of tape on end of core.

To assure correct positioning of Mark #1 do the following. Holding the exposed core, slide cover as far back towards the tightly tied slip knot as you can. Then, firmly smooth cover back from the slip knot towards taped end. Smooth again until all cover slack is removed. Then, mark core where it comes out of cover. This is Mark #1. Do this to both ropes.





*with wire fid double measurements up to 13" cir.

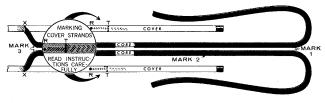
Hold one core at Mark #1 and slide cover back to expose more core.

From Mark #1, measure along core towards X a distance equal to the short section of fid *and make two heavy marks. This is Mark #2.

From Mark #2, measure in the same direction **one fid length plus another short section** *and make three heavy marks. This is Mark #3.

Mark second core by laying it alongside the first and using it as an exact guide.







Note nature of the cover braid. It is made up of strands. By inspection you can see that half the strands revolve to the right around the rope and half revolve to the left.

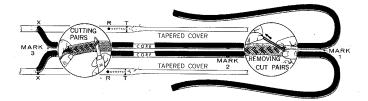
Beginning at R and working toward the taped end of cover, count 8 consecutive pairs of cover strands which revolve to the right (or left). Mark the 8th pair. This is Point T (See Insert). Make Mark T go completely around cover.

Starting at T and working toward taped cover end **count** and **mark every second right pair** of strands for a total of 6. Again, starting at T, count and mark every second left pair of strands for a total of 6. (See Insert).

Make both ropes identical.



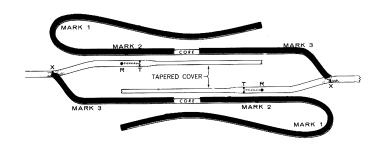
PERFORMING THE TAPER . . . STEP 5



First remove tape from cover end. Starting with last marked pair of cover strands toward the end, cut and pull them completely out (See Insert). Cut and remove next marked strands and continue with each right and left marked strands until you reach Point T. **Do not cut beyond this point.** (See Insert)

Retape tapered end.

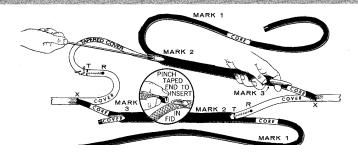
Cut and remove marked strands on the other marked cover, again stopping at T. Retape tapered end.



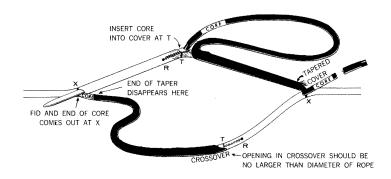
Reposition ropes for splicing according to diagram. Note how cover of one rope has been paired off with core of the opposite line. **Avoid twisting.**



* T... PUTTING THE COVER INSIDE CORE



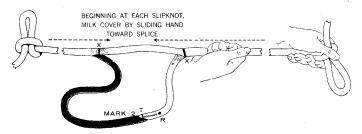
Insert fid into one core at Mark #2 and bring it out at Mark #3. Add extra tape to tapered cover end then jam it tightly into hollow end of fid (see insert). Hold core lightly at Mark #3, place pusher point into taped end pushing fid and with cover in it from Mark #2 out at Mark #3. When using wire fid, attach fid to cover. Then pull fid through from Mark #2 to Mark #3. Pull cover tail through core until Mark T on cover meets Mark #2 on core. Insert other cover into core in same manner.



Now put core back into cover from T to X. Insert fid at T, jam taped core tightly into end of fid. With pusher, push fid and core through cover bringing out at Point X. When using wire fid attach fid to taped core. Then pull fid and braid through from T to X. Do this to both cores. Remove tape from end of cover. Bring crossover up tight by pulling on core tail and on tapered covered tail. Hold crossover tightly smoothing out all excess braid away from crossover in each direction. Trim end of Tapered cover on an angle to eliminate blunt end. Tapered cover tail will disappear at Mark #3. Cut core tail off close to Point X at an angle.



BURYING THE EXPOSED CORE . . . STEP 9



Hold rope at slipknot and with other hand milk cover toward the splice, gently at first, and then more firmly. The cover will slide over Mark #3, Mark #2 the crossover and R. Repeat with the other side of the splice.

Continue burying until all cover slack between the knot and the splice has been removed.



CONTINUE "MILKING" - REMOVE ALL COVER SLACK

END OF BURIED SECTION CROSSOVER POINT BURIED TO APPROXIMATELY HERE

The splice is done when all cover slack has been removed and there is an opening in the splice approximately equal in length to the diameter of rope. If at the opening one side of the splice is noticeably longer than the other side, something is wrong. Check Steps 1-9 and remake if necessary.

Now untie the slip knots.

Chapter 7: Marlinespike Seamanship

